The Grass Farmers Love To Hate

If your lawn has tall fescue grass, you can be more than 90 percent certain that the fescue is infected with a toxic fungus called *Neotyphodium coenophialum*.

But before you get on the phone to complain to your lawn company, you should know that this fungus is why you love your lawn. The fescue and the fungus have a mutually beneficial relationship. The fungus lives in the stem of the grass, between cells, so it doesn't harm the plant. Instead it helps tall fescue withstand many extremes—from poor soils to hot and cold temperatures to dry and wet conditions.

Equally important, the fungus and fescue interact to produce an array of alkaloids that help the plant persist. The alkaloids deter attacks from viruses and other diseases, as well as from insects and microscopic worms that eat plant roots.

The alkaloids also affect livestock grazing behavior. Unfortunately, the result can be serious production losses, particularly when they cause cows to stop eating.

Tall fescue persists better with grazing than any other cool-season grass. That's why it is grown throughout the world. It's an important cool-season perennial forage for many cattle producers in the southeastern United States, in addition to its importance as a lawn grass. Kentucky-31 tall fescue, an old standard, covers 35 million acres of pastures in the Southeast.

Agricultural Research Service scientists and their university colleagues have found that the *N. coenophialum* fungus seems to perform an important ecological function, helping the plant store more organic carbon and nitrogen in the soil. They have also found that it helps fescue close its leaf stomates quicker to conserve moisture in a drought, as well as improve growth efficiency.

In return, the fescue gives the fungus a home and a way to get water, energy, and nutrients. It also gives the fungus a way to propagate itself by infecting seed so it can live in the new plants.

The positive and negative relationship was discovered by ARS and university scientists in the late 1970s and 1980s, beginning with the discovery in 1977 of the first direct link between the fungus and cattle disease symptoms—by ARS microbiologist Charles W. Bacon, with the ARS Toxicology and Mycotoxin Research Unit, in Athens, Georgia, working with ARS chemist James K. Porter, ARS animal scientist Joe D. Robbins, and University of Georgia colleague E.S. Luttrell.

What Goes on Down Below

Just recently, agronomist David P. Belesky and his colleagues, including visiting scientist Dariusz Malinowski, at the ARS Appalachian Farming Systems Research Center, in Beaver, West Virginia, discovered one way the fungus helps tall fescue in poor soils. He found that the fungus causes the plant's roots to

JOHN STUEDEMANN (K8930-2)

Toxic alkaloids in tall fescue can make cows sick. The cow in the foreground has consumed so much of these compounds that she is ill.

For the beef industry, tall fescue toxins cost anywhere from $500 million to $1 billion a year in fewer births and lower weight gains.

grow finer and more fibrous. This enables the roots to capture more nutrients, such as phosphorus, that are scarce in poor soil, as well as more water for both the plant and the fungus.

Belesky notes, “The beneficial relationship is an aboveground-belowground version of the standard underground mychorrhizal relationship found in many plants—a beneficial cohabitation between fungi and roots. The mychorrhizal fungi live on the roots and physically extend the plant’s reach for nutrients and water with hairlike tentacles called hyphae.

“What we’ve found with tall fescue,” says Belesky, “is a case where the fungi live in the plant stem but still modify the plant roots to grow differently for the same purpose—taking in more water and nutrients. They also cause the roots to leak compounds that help roots acquire scarce nutrients and protect roots against soil acidity and accompanying toxic elements, such as some forms of aluminum.”

Toxins Are Good, Bad, and “Ugly”

Because of benefits such as these, both plants and farmers would have difficulty living without these fungi. ARS and university scientists in Georgia have worked closely to retain the benefits while minimizing the negatives—by developing new varieties and a vaccine to protect animals against those alkaloids in tall fescue that are toxic.

The toxic alkaloids are harmless on lawns, where animals don’t usually graze—at least not extensively enough to cause problems. Eating a few leaves now and then, as dogs and cats do, is not a problem.

Not so for livestock. For the beef industry, the toxins cost anywhere from $500 million to $1 billion a year in fewer births and lower weight gains. For the horse industry, losses are harder to estimate but could be even higher than those for the beef industry because of the much higher price tags on horses. Eating infected fescue often causes extended pregnancies in mares, resulting in foaling problems.

Although dairy cows don’t usually graze in pastures of tall fescue, those that do often produce less milk. Sheep don’t do well on tall fescue pastures either and also are not typically found on fescue pastures.

The toxins affect cardiovascular, central nervous, and endocrine systems in livestock. Cattle with fescue toxicosis—the collective name for the toxin’s symptoms—often lose the ability to regulate their body temperature as the veins constrict in their hooves, tails, and ears. In hot weather, this internal overheating causes them to stop eating and seek cool places. The poor blood circulation can

SCOTT BAUER (K8930-1)

University of Georgia immunologist Donald Dawe (left) vaccinates a steer against fescue toxicosis as ARS animal scientist John Stuedemann assists. The vaccine was developed by Stuedemann and his colleagues.

also cause gangrenous lesions on the extremities, resulting in loss of hooves or parts of ears and tails. In addition, they have a rough coat that gives them a disheveled appearance.

“The symptoms are most noticeable in Angus cattle because it changes their nice, black, shiny coats to a rough bronze color,” Belesky says. Other possible symptoms include lethargy and rapid breathing. It can also cause deformities and paralysis.

“There is no cheap way to prevent or treat fescue toxicosis at this time,” Belesky says. “The only ways farmers can currently cope with it are time-consuming and expensive, like moving cows to other pastures or feeding them supplements.”

University of Georgia (UGA) researchers found that fescue plants dictate the amounts of alkaloids produced by the fungus. They used traditional plant breeding approaches to develop new germplasms that make the fungus produce lower amounts of alkaloids.

These new germplasms are being evaluated by animal scientist John A. Studemann at the ARS J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, Georgia.

Fescues With Less Toxin

Stuedemann and his ARS colleagues are setting up 14 pastures—each a complete watershed—to test candidate plants for alkaloid production and their effect on everything from cattle performance to carbon storage. They will also test the effects of chicken litter and commercial fertilizers on the toxicity of the pastures.

The scientists will check the quality of the water leaving the pastures. They want to make sure that too much nitrogen, phosphorus, alkaloids or other biologically active compounds, or pathogens are not contaminating surface water and groundwater.

Stuedemann began working on fescue toxicosis when he joined ARS in 1970. Back then, the thinking was that fertilizing fescue with poultry litter or high rates of inorganic fertilizers was causing the symptoms. At the time ARS had not yet discovered the accompanying fungus.

SCOTT BAUER (K8928-1)

Animal scientist Dwight Seman samples solutions from parabiotic chambers that simulate parts of a cow's stomach. The purpose is to determine whether alkaloids pass through stomach tissue into the bloodstream.

SCOTT BAUER (K8932-1)

Stomach tissue from a sheep is placed between halves of a glass parabiotic chamber. Alkaloids are added to one side of the tissue to see whether they are transported through the tissue to the other side.

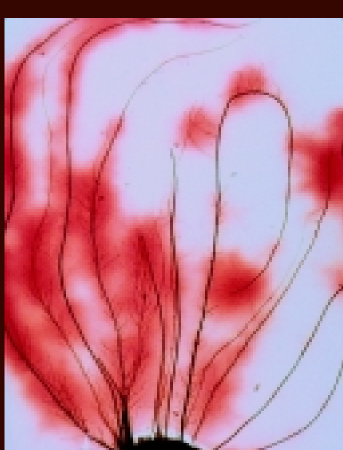
"Ironically, we've come full circle," Stuedemann says. "Now we're checking to see whether poultry litter aggravates toxicosis symptoms." Stuedemann travels to various states to discuss this potential with farmers, industry, and researchers.

While there are fungus-free fescues on the market, Stuedemann doesn't see them as a solution to toxicosis. The absence of the fungus makes the fescue too vulnerable to being devoured by insects or wiped out by disease or overgrazing.

Belesky, who began his career at Watkinsville in 1978 and transferred to Beaver in 1988, says discovering how the fungus improves tall fescue and confers ecological benefits could help Stuedemann and his colleagues as they create new varieties.

"If they could find tall fescue plants in which the fungus 'orders' the roots to grow better and release soil-improving compounds, while the plant orders the fungus to produce only safe and protective alkaloids, they'd be in business," says Belesky.

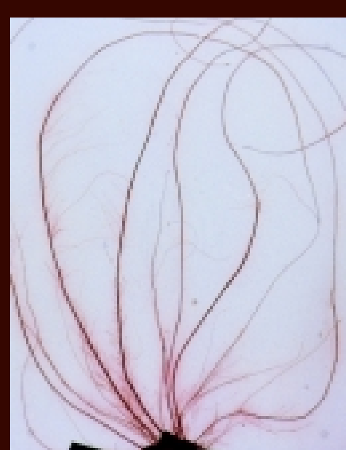
DARIUSZ MALINOWSKI (K8934-2)



Left: Stained exudates from fungus-infected tall fescue roots are red. Exuded compounds can protect roots from excess soil acidity and toxic elements.

Right: Roots from a genetically identical tall fescue plant that is fungus-free produce fewer exudates.

DARIUSZ MALINOWSKI (K8934-5)



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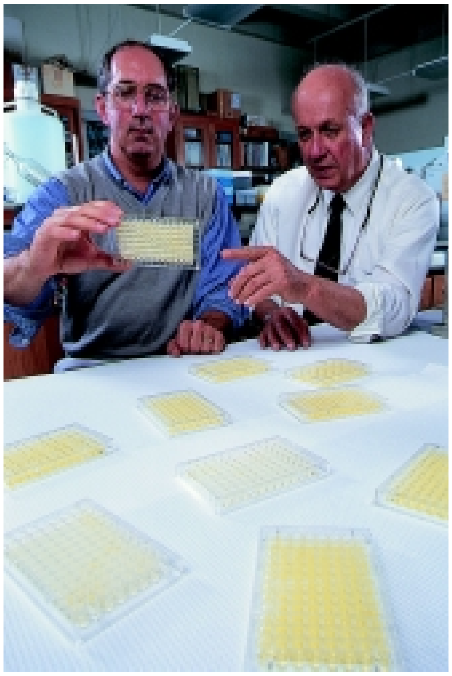
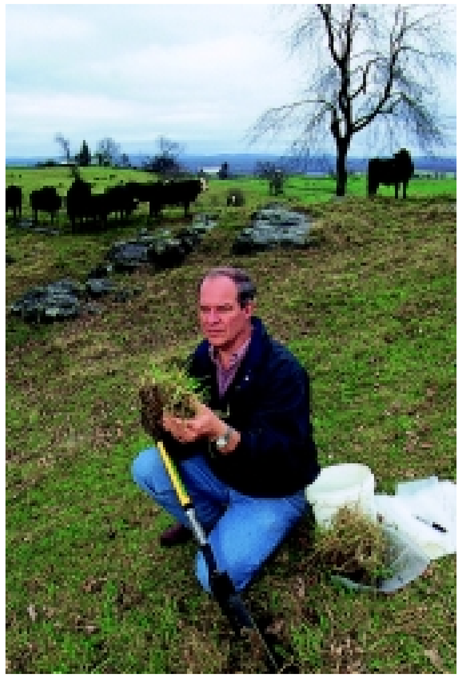


Crop scientist Nick Hill (left) and animal physiologist Fred Thompson of the University of Georgia perform immunochemical tests to study toxins in pasture and urine samples.

SCOTT BAUER (K8934-4)



Agronomist David P. Belesky collects tall fescue samples from a pasture. The bases of the stems will be cut into sections, stained, and examined under a microscope to see whether the fungus is present.

Diagnostic Urine Test

Stuedemann's work so far suggests that cattle's ruminal microbial digestion rapidly affects the release of the alkaloids from plant tissue and subsequent absorption of the alkaloids or their byproducts in the bloodstream.

But scientists don't know which alkaloids are responsible for fescue toxicosis. "For all we know, the toxin could be a smaller byproduct formed as the animal digests or metabolizes an alkaloid," Stuedemann says.

He got that hint when he and his university colleagues decided to examine animal excretion routes, the biliary and urinary systems, of absorbed compounds.

"We found that about 94 percent of the alkaloids excreted were in urine," Stuedemann says. "This was a surprise because the most common alkaloid in tall fescue, ergovaline, seems to be too large a molecule to be excreted this way, so maybe it's broken down into smaller byproducts.

"We also found that within 24 hours after calves were transferred from fungus-free fescue to fungus-infected fescue, their urinary alkaloid content was as high as if they'd been grazing fungus-infected fescue for months."

Vaccine in the Making

Stuedemann and his colleagues developed the urine test as an offshoot of their vaccine work. They have patented a vaccine prototype that is too short-lived—lasting 4 to 5 weeks—to be practical.

"To protect animals against tall fescue's fungal toxins, a vaccine would have to last at least 3 to 4 months," Stuedemann says. "This length of time would carry the animal through the spring and early summer, when toxin levels are highest." He and colleagues are fine-tuning the vaccine to make it a commercial success.

But first, the researchers are taking a step back, having realized that they need to find out which toxins are reaching the cattle's bloodstream and how and where they're getting through the stomach lining into the blood.

To do this they are doing experiments in small chambers, called parabiotic chambers, that use stomach tissue from sheep to simulate that of the rumen and the omasum, two of the four compartments in a cow's stomach.

The rumen is the largest compartment and serves as a fermentation vat for microbial digestion of grasses. The omasum uses muscle action to press and further break down chewed grass cud into smaller pieces and squeeze out excess water. Alkaloids from the fungus are put into the chambers to see which ones make it through the stomach tissue and how and where they get through.

"Once we know that, we can tailor the vaccine to target the correct toxin at the right site—blocking the toxin from entering the bloodstream," Stuedemann says.—By **Don Comis,** ARS.

This research is part of Rangeland, Pasture, and Forages, an ARS National Program (#205) described on the World Wide Web at http://www.nps.ars.usda.gov/programs/appvs.htm.

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